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Association Of Health Problems with 50-hz Magnetic Fields in Human Adults Living Near Power Transmission Lines

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Abstract

Although numerous studies of animals and cell cultures indicate effects of power-frequency magnetic fields on immune-system function, few studies have looked for evidence of association between environmental power-frequency magnetic field exposure and immune-related illnesses in humans. This study used a cross-sectional design to examine the dose-response relationship between magnetic-field exposure of adults in their homes and prevalence of immune-related and other chronic illnesses. Five-hundred-and-sixty adults living near extra-high-voltage transmission lines completed questionnaires about their health and demographic characteristics. Derived health variables were related to individual estimates of time- integrated magnetic field exposure. Five of the eight health variables showed a linear dose-response relationship with exposure. After adjustment for possible confounding, significantly elevated odds ratios were obtained at higher exposure levels both for asthma and for combined chronic illnesses. The results are consistent with a possible adverse effect of environmental magnetic field exposure on immune-related and other illnesses.

Introduction

The accumulating evidence that residential exposure to power-frequency magnetic fields is associated with elevated risk for childhood leukaemia[e.g.1,2] has led to concern that such field exposures may adversely affect immune-system function.[3,4] While some laboratory studies, both of live animals and human cell cultures, have demonstrated effects of weak power-frequency fields on immune function at the cellular level[5-9], extrapolation of such findings to residential exposure and human health is considered problematic.[10]

To date there have been few studies of health effects on adults of residential exposure to power-frequency fields, these largely being confined to leukaemia and central nervous system tumours[11-13] or mental health.[14,15] Our study addresses the broader subject of a possible association between power-frequency magnetic field exposure and the incidence of immune-related diseases and other chronic health problems in adults.

Previous epidemiologic research has methodological weaknesses that limit its power to provide strong evidence for adverse effects of 50/60-Hz exposure. Three of the problems identified are: poor exposure assessment of individuals; insufficient control of possible confounding variables; and, inability to demonstrate a systematic dose-response relationship.[e.g. 16] Our study attempted to address these methodological problems in several ways: We employed a cross-sectional design intended to maximize the range of individual field exposures and therefore the possibility of finding a systematic dose-response relationship; we interviewed individual participants in an attempt to measure a wide range of possible confounders; and, we obtained direct measures of individual time-integrated exposures to 50-Hz magnetic fields so that we could estimate participants' overall history of residential exposure to 50-Hz fields.[17]

We hypothesised that the prevalence of immune-related diseases would be related to the magnitude of residential exposure to 50-Hz magnetic fields.

Method

Topographic maps of the Auckland Metropolitan area were used to locate streets running beneath or adjacent to overhead transmission lines connecting substations in the national grid. 50-Hz magnetic field flux densities were measured at the gateways of houses in these streets and letters were left in the mailboxes of all houses where gate readings exceeded 5 mG. For each such house, another house was selected in the same street with a gate reading less than 3 mG. This was to ensure that the initial sample would include a range of magnetic field levels above 5 mG and below 3 mG taken from comparable localities. The letter gave general information about the purpose of the study and invited residents between the ages of 15 and 72 years, who had resided for at least six months at that address, to agree to participate by phoning the researcher or by returning a consent form by post. Participants were recruited at a follow-up visit when their status to participate was confirmed and written consent was obtained after any questions had been answered by the researcher. Consent included agreeing to have medical records checked by the participant's medical practitioner and to have blood samples taken. The informed consent procedure was approved by a university ethics committee.

Interviewing and field measurement were done by senior psychology students under the supervision of qualified and experienced researchers. The interviewers were trained to a mastery criterion on all the skills relevant to data collection, which included making neutral responses to typical questions by participants about the effects of magnetic fields, questionnaire administration, and field measurement. Initial interviews were directly supervised by a researcher and subsequent interviews were monitored on a random basis as a means of quality control. Interviews took about 90 minutes and took place in a quiet area in each participant's home at a time convenient to the participant. Interviewers worked in pairs for reasons of personal safety and to facilitate supervision of children during interview of a parent.

Measures

The questionnaires given, in order of administration, were as follows:

The Life Changes Questionnaire.[18] This is a list of 38 life events. Participants indicated which events had occurred in their lives within the past 12 months. The score was the sum of marked events, weighted according to their typical effect on mental health.

The Powerlines Project Questionnaire. This was developed specifically for the study, to collect relevant demographic, general behavioural and health information. It included questions to determine age, gender, education, occupation, health problems, medication use, alcohol use, and years resident at current address. At the end of the questionnaire participants were asked to rate their general health over the past six months on a 5-point scale from "terrible" to "excellent".

Additional tests of cognitive functioning and mental health were also given at this time but these are reported separately.[15]

Scoring of questionnaires. Questionnaires were scored by researchers from records that did not indicate the address of the participant nor the field measurements taken at the address. Thus the scorer was 'blind' to the magnetic field exposure relevant to each record.

Participants' responses to questions about their health were sorted into eight variables which were analysed to test hypotheses about association between magnetic field exposure and health problems. Four of these variables reflected either general health or particular types of health problem. *Self-rated health* was measured from responses to a question that required participants to rate their general health during the past six months, by circling the appropriate word on a five-point scale from "terrible" to "excellent". Responses were dichotomised (point 3 or below =0, above point 3=1) for analysis. Incidence of *chronic illnesses* was measured by asking participants to name any chronic illnesses they suffered from for at least the past six months and for which medication was prescribed by a medical practitioner. Participants were scored as having an *allergy-related illness* if medicated for hay fever, food allergies, asthma, eczema, urticaria, dermatitis, or psoriasis. They were scored as having an *autoimmune-related illness* if medicated for rheumatoid arthritis, thyroiditis, Graves' disease, Sjogren's syndrome, ulcerative colitis, Crohn's disease, systemic lupus erythematosus, pernicious anaemia, autoimmune chronic active hepatitis, myasthenia gravis, multiple sclerosis, Goodpasture's syndrome, or type-I diabetes.

The other four variables reflected specific diseases. *Colds and flu* were measured by asking participants to indicate the number they had suffered in the past six months. Responses were dichotomised (any vs. none) for analysis. *Type-II diabetes*, *asthma* and *rheumatoid arthritis* were scored if a participant reported both being diagnosed and prescribed medication.

Field measurements. At the end of the interview, participants were asked to indicate in which rooms of the house they spent one hour or more per day on average. The estimated time spent in each room was noted. Interviewers then used gauss meters (MSI-50; Magnetic Sciences International) to record 50-Hz magnetic flux densities at three places in each nominated room. During this time, the normal pattern of appliance use was continued, but no readings were taken closer than 1 metre to appliances. In bedrooms, one reading was recorded at the head of the bed, one in the middle of the bed, and one away from the bed. The time of day when the readings were taken was also recorded. Because field measurements would be expected to vary to some extent according to variations in current loadings on the transmission lines at various times of the day and seasons of the year, an assessment was made of the representativeness of the field measurements taken following the regular interviews. A researcher re-visited 38 randomly chosen participants and repeated the field measurement protocol. The time, day and month were chosen to suit the participants, without reference to the previous measurement occasion. The local geomagnetic field was measured at six representative locations at the conclusion of the study, using an Elsec 820 proton precession magnetometer (Littlemore Scientific Engineering Co., Oxford, U.K.).

Results

Participants

Of the 704 households approached, 330 did not yield anyone willing to participate. The other 374 households yielded a total of 572 participants, 560 of whom met all the inclusion criteria and completed the relevant questionnaires. Fifty-five people consenting initially [redacted] study because subsequently they failed to [redacted] administration of tests or questionnaires. [redacted] excluded because they indicated that they [redacted] ing interviewed in the English language. Twenty-four were excluded because they had resided less than six months at that address and a further ten were excluded because they were about to change address. Six were excluded for reasons of physical incapacity and twenty-five excluded because they were older than 72 years. Table 2 shows demographic data for the whole sample and for each quintile (see next section).

Magnetic field characteristics.

The 50-Hz magnetic field flux density measurements are summarised in Table 1. Two indexes of average exposure were derived for each participant. Average exposure was the arithmetic mean of all readings taken in the two or three rooms in which the participant spent one hour or more per day on average. Time-integrated exposure was derived by multiplying the average estimated hours spent in each room by the mean of the readings taken in the room, and summing across the rooms in which the participant spent one or more hours per day on average. The Pearson correlation between the two exposure indexes was 0.96.

Test-retest reliabilities were calculated as Pearson reliability coefficients for average exposure (r=0.915, N=38) and time-integrated exposure (r=0.90, N=38). The coefficients were calculated on the 38 pairs of values obtained from field measurements and time estimates taken at the first and second visits.

The mean flux density of the local geomagnetic field was 544 mG (range 543-547 mG).

TABLE 1. Magnetic flux density at 50-Hz

	N	Mean	Min	Max	S.D.
Individual reading (mG	4557	6.92	0.01	194.30	9.02
Room mean (mG)	1519	6.92	0.01	141.2	9.02
Average exposure (mG)	560	6.74	0.01	75.80	8.08
Time-integrat exposure (mG-hour)	560	100.14	0.03	974.33	125.61

Table 2 shows values grouped according to quintiles, with 112 participants in each.

The quintiles are based on the distribution of time-integrated exposure; however, average exposure values for each quintile are also reported because this exposure measure has been widely used in previous

TABLE 2. Exposure values for quintiles based on time-integrated exposure

	Quintiles				
	1	2	3	4	5
N	112	112	112	112	112
Mean average exposure (mG)	0.57	2.09	3.92	7.66	19.44
S.D.	(0.44)	(0.77)	(1.03)	(2.55)	(9.42)
Min.	0.01	0.80	1.83	3.22	7.71
Max.	2.14	4.93	6.80	18.80	75.80
Mean time-integrated exposure (mG-hour)	6.40	27.56	53.33	105.79	307.61
S.D.	(4.18)	(6.93)	(9.37)	(22.46)	(137.6)
Min.	0.03	14.89	39.26	71.00	51.10
Max.	13.93	38.93	70.80	150.60	974.33

studies and is easier to relate to current knowledge about typical environmental exposure levels.

All health measures were analysed using the same procedure. First, the number of people classified as 'cases' and 'non-cases' were calculated for each exposure quintile, and a χ^2 test for linear trend conducted to test for a significant linear dose-response pattern.[19] These results are shown in Table 3.

TABLE 3. Characteristics of participants in whole sample and separate quintiles

	Whole Sample	Quintiles				
		1	2	3	4	5
N	560	112	112	112	112	112
Female (%)	53.9	58.0	51.8	45.5	55.4	58.9
Age (mean years)	40.5	42.0	38.3	40.4	41.7	40.0
SES (mean level)	3.6	3.3	3.5	3.7	3.7	3.9
Ethnic identity						
% European	75.4	82.2	75.0	85.6	75.0	58.9
% NZ Maori	10.0	6.2	7.2	7.2	11.6	17.9
% Pacific Island	10.2	9.8	8.0	3.6	10.7	18.7
% Other	4.5	1.8	9.8	3.6	2.7	4.5
Mean duration of residence (years)	10.9	10.6	9.9	9.3	13.1	11.4
Educational level (mean)	1.4	1.6	1.6	1.4	1.4	1.3

Next, time-integrated exposure was dichotomised (quintile 1 & 2 = less-exposed, quintile 4 & 5 = more-exposed). Participants in quintile 3 were excluded to avoid possible misclassification into upper and lower exposure categories. For each health measure, the proportions of cases and non-cases falling into the two exposure categories were examined using the Mantel-Haenszel procedure to obtain crude estimates of prevalence odds ratios (OR) and their associated 95% confidence limits. These results are shown in Table 4.

Table 4. Percent in each quintile classified as "case" on each health measure and c² statistics for linear association with exposure

	Exposure quintiles					χ^2	*p*
	1	2	3	4	5		
N	112	112	112	112	112		
self-rated health	8.2	9.0	5.6	14.6	18.2	5.78	0.016
chronic illnesses	12.5	7.1	11.6	18.8	20.5	7.06	0.008
allergy-related	8.9	5.4	9.8	5.4	8.0	0.05	0.82
autoimmune-related	8.0	3.6	4.5	9.8	10.7	2.22	0.13
colds and flu	17.0	22.3	15.2	16.1	20.2	0.00	0.994
asthma	1.8	2.7	6.2	5.4	8.0	5.61	0.017
type-II diabetes	0.9	0.0	0.9	4.5	2.7	4.12	0.042
arthritis	5.4	2.7	4.5	6.3	7.1	1.16	0.28

Variables considered to be possible confounders were tested for significant association with caseness for each health measure. The variables were entered simultaneously with the dichotomised exposure classification in a multiple logistic regression, with the health measure as dependent variable.[20] Selected variables were age (dichotomised by median split), gender, SES (median split), ethnicity (Caucasian vs. other), smoking (yes or no), alcohol (none/occasional vs. heavy), years resident at address (median split), educational qualification (secondary vs. tertiary) and life changes (median split of score on Life Changes questionnaire). Participants' beliefs about whether living near powerlines had any effect on their health was also included. Belief was indicated on a 5-point scale from "definitely improved it" to "definitely made it worse". Scores on this scale were dichotomised according to whether participants scored "possibly made it worse"/ "definitely made it worse" vs. any other belief. Variables were analysed further only if they were found to be significant predictors in the regression equation, based on a liberal criterion ($p<0.20$). Estimates of prevalence odds ratios were then re-calculated, simultaneously adjusting for the influence of the selected variables by using the Mantel-Haenszel procedure for weighted OR. The adjusted ORs are shown in Table 5 (page 12).

Table 4 shows that there was a significant linear association between the proportion of cases and exposure level for self-rated health, chronic illnesses, asthma and type-II diabetes. Colds and flu and allergy-related diseases were not systematically related to exposure level. Although autoimmune-related illnesses showed a significant linear trend between quintiles 2 and 5 (χ^2=6.04, p=0.01), the reversal of direction of trend between quintiles 1 and 2 results in the overall trend being non-significant. A similar reversal of trend between quintiles 1 and 2 was shown in 5 of the 8 variables. The analysis of proportions of cases across dichotomously classified exposure categories (Table 5) showed significant elevation of risk at the higher exposure category only for self-rated health (OR=2.1), chronic illnesses (OR=2.2), asthma (OR=3.1) and type-II diabetes (OR=8.3). When the OR was adjusted for possible confounders, there was some decrease in size of ORs for all variables except asthma. In particular, the adjusted relative risk estimates for self-rated health and type-II diabetes fell to non-significant levels, lower 95% confidence intervals (CIs) having values less than 1.0. For self-rated health, the strongest confounder was ethnicity, which on its own reduced the OR by 14%. For type-II diabetes, the strongest confounding was with the interaction between ethnicity and age, affecting OR by 23%. Although participants' beliefs about the effects of powerlines on their health influenced the relation between exposure and 5 of the 8 health variables, its effect on OR estimates was important only for self-rated health (6.3%).

Discussion

Linear dose-response functions are considered to be evidence for existence of a health hazard,[21] and are regarded as giving a much better description of the relation between exposure and health than the usual contrasting of extremes or dichotomies such as exposed versus unexposed.[22] The range of average exposure levels of participants in our study extended from 0.01 mG to 75.8 mG. This is in contrast to the smaller range (0.2 - 3.5 mG) over which dose-response patterns have been reported in studies of cancer.[22] Our results indicated that, for adults living near transmission lines, the prevalence of chronic illness was linearly related to the level of 50-Hz magnetic field exposure. A similar association was found for self-rated health status and for some specific illnesses, particularly asthma and type-II diabetes. Autoimmune-related illnesses collectively were significantly linearly related to exposure over most of the exposure range (quintiles 2 through 5).

The process of risk estimation is simplified by contrasting health problems in exposed and unexposed populations. The analysis of health problems in the less-exposed vs. more-exposed participants showed that the crude estimate of prevalence ORs for health problems on those variables showing linear dose-response patterns ranged from 1.7 (arthritis) to 8.3 (type-II diabetes). After adjustment

Table 5. Numbers of people classified as "cases" and "non-cases" on each health variable. Crude and adjusted prevalence Odds Ratios (OR) and their associated 95% confidence intervals (CI) are also shown

	Less exposed		More exposed									
	cases	non-cases	cases	non-cases	Crude OR	95%	CI	Adj OR	95%	CI	*p*
self-rated health	15	159	29	148	2.1	1.1,	4.3	1.4	0.6,	3.5	0.48
chronic illnesses	22	202	43	180	2.2	1.2,	4.0	2.1	1.1,	4.0	0.02
allergy-related	16	208	15	209	0.9	0.4,	2.1	.89	.44,	1.8	0.88
autoimmune-related	13	211	23	201	1.9	0.9,	4.0	1.8	0.7,	4.4	0.24
colds and flu	44	180	40	181	0.9	0.6,	1.5	0.9	0.6,	1.3	0.45
asthma	5	219	15	209	3.1	1.1,	10.1	3.3	1.1,	10.5	0.04
type-II diabetes	1	223	8	216	8.3	1.0,	177	6.5	0.7,	137	0.15
arthritis	9	215	15	209	1.7	0.7,	4.3	1.2	0.4,	3.7	0.87

for the confounding influence of other variables, however, significant elevations of risk associated with higher exposure were confined to two health variables, chronic illnesses (2.1) and asthma (3.3). These elevations are large compared to those reported in most other studies of health effects of residential magnetic-field exposure, including those on childhood leukaemia.[2]

The exposure-level threshold for increased risk can be only crudely estimated from our data. The lower boundary of time-integrated exposure for the high-exposure category was 71.0 mG-hour and the mean was 206.65 mG-hour. The upper boundary of the low exposure category was 38.93 mG-hour and the mean was 16.98 mG-hour. The distributions of mean exposure levels (without time integration) in the two exposure categories overlap somewhat, the minimum for the high-exposure category being 3.22 mG and the maximum for the lower exposure category being 4.93 mG. This threshold region for increased risk in this study is more than a hundred-fold lower than the maximum permissible exposure limit (1000 mG) for the general public recommended in the relevant international guideline.[23]

It is possible that the relations between exposure level and health measures found in this study are due to some factor other than the potential confounders we identified and controlled for (e.g., exposure to environmental chemical toxins). However, such confounders would have to be correlated with field exposure over a wide range to yield the dose-response pattern found in this study. Another possibility is that the association we found is a direct result of biased reporting of health problems, with a bias for reporting health problems being positively correlated with level of field exposure. This bias would arise if more-exposed people were more likely to associate health problems with exposure and therefore more likely to report them in the context of an investigation of effects of exposure. The measure of 'perceived effect' was included in the analysis to eliminate this source of confounding.

We hypothesised that immune-related illnesses would be more prevalent in participants with higher magnetic-field exposure. One immune-related illness, asthma, was strongly associated with exposure level. Also, many of the chronic illnesses reported were immune-related, although there were too few cases of most specific diseases to permit useful analysis. Significant ORs were not found for colds and flu, nor for the collective categories of allergy-related or autoimmune-related illnesses. For the latter, however, there was evidence of a linear dose-response pattern. The results are interpreted as consistent with the idea that the immune system is influenced by exposure, but the influence is not uniformly expressed in all immune-related diseases.

The scoring of illnesses in our study was based entirely on self report about professional diagnosis and treatment prescription and not validated against medical records. The fact that participants consented to checking of their medical records does not guarantee accurate self-reporting, though inaccurate reporting would not be expected to be correlated with exposure level, other than in the sense that it was controlled for by inclusion of the 'perceived effect' variable. These issues are of particular concern for the asthma findings since it is well-known that asthma sometimes is not diagnosed. For this reason some surveys focus on questions about asthma symptoms[24,25] rather than diagnosed asthma, which is more likely to be affected by health beliefs, access to health services and diagnostic practice. The asthma findings should therefore be interpreted with caution. Nevertheless, it is reassuring that many illnesses (e.g., allergies, colds and flu, arthritis) were not found to be associated with exposure, indicating that there was no general tendency for over-reporting of health problems by more-exposed participants.

Further study of magnetic-field exposure and immune-related illnesses is clearly warranted, including investigation of specific immune variables.

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